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Physicochemical and microbiological evaluation of water coming from alternative solutions of supply in the Metropolitan Region of *Baixada Santista*, São Paulo State, Brazil

Avaliação físico-química e microbiológica de águas procedentes de soluções alternativas de abastecimento na Região Metropolitana da Baixada Santista, Estado de São Paulo, Brasil

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ABSTRACT

Water is essential to life but its contamination may endanger public health. This study evaluated the physical-chemical and microbiological quality of alternative water supply solutions located in the Baixada Santista / SP. 67 samples (41 water spouts, 13 springs and 13 wells) were initially collected, and then 22 new collections were made. Total coliforms and *Escherichia coli*, according to the methodology of APHA (2012) and the contents of chloride, free residual chlorine (in treated waters), apparent color, hardness, iron, fluoride, nitrate, nitrite, odor, pH, total dissolved solids, and sulfate turbidity, were counted according to the techniques described by ANVISA (2005). Of the total of the samples, 56 (83,6%) were not in compliance with Decree 2914/2011 of the Ministry of Health, which refers to the potability of water for human consumption. The tests with the highest percentage of unsatisfactory results were *E. coli*, 39 (58,2%); apparent color 16 (23,9%) and nitrate, 15 (22,4%). A frequent monitoring of the quality of these waters is suggested – carrying out measures for their treatment, such as chlorination-, as well as a clarification to consumers about the quality of these waters by the competent bodies and the media for the benefit of the population's health.

KEYWORDS: Drinking Water; Water Supply; Microbiologial Evaluation; Physical-chemical Evaluation; Public Health; Sanitary Surveillance

RESUMO

A água é indispensável e essencial à vida, mas sua contaminação pode colocar em risco a saúde pública. Foram avaliadas a qualidade físico-química e a microbiológica da água de soluções alternativas de abastecimento localizadas na Região Metropolitana da Baixada Santista/SP. Foram coletadas 67 amostras (41 de água de bicas, 13 de nascentes e 13 de poços) e realizadas 22 novas coletas, quanto à pesquisa e contagem de coliformes totais e *Escherichia coli*, conforme a metodologia da APHA (2012) e os teores de cloreto, cloro residual livre (nas águas tratadas), cor aparente, dureza, ferro, fluoreto, nitrato, nitrito, odor, pH, sólidos totais dissolvidos, sulfato e turbidez, segundo as técnicas descritas pela Anvisa (2005). Do total, 56 (83,6%) foram reprovadas com base na Portaria nº 2.914/2011 do Ministério da Saúde, que dispõe sobre a potabilidade da água para consumo humano. Os ensaios com maior percentual de resultados insatisfatórios foram: *E. coli*, 39 (58,2%); cor aparente, 16 (23,9%) e nitrato, 15 (22,4%). Sugere-se um monitoramento frequente da qualidade das referidas águas, a realização de medidas para o seu tratamento, como a cloração, e um esclarecimento aos consumidores quanto à qualidade dessas águas por parte dos órgãos competentes e da mídia em benefício da saúde da população.

PALAVRAS-CHAVE: Água Potável; Abastecimento de Água; Avaliação Microbiológica; Avaliação Físico-química; Saúde Pública; Vigilância Sanitária

INTRODUCTION

Earth surface is two-thirds covered by water, but only 2.5% of the total is fresh water and only 0.3% is stored in rivers and lakes, available for consumption in various activities[1].

Water is indispensable to all living things, but if contaminated it can become a public health problem, causing diarrhea, intestinal infections and other diseases, possibly leading to death[2].

Water quality is closely related to some diseases that affect the population, especially in areas that basic sanitation, since bad sanitary conditions degrade water resources, as is often the case in Brazil[3].

Roughly 90% of the deaths caused by diarrhea are attributed to bad water quality and lack of basic sanitation and hygiene[4]. One of the most significant forms of water pollution is inadequate sanitation, which contaminates watercourses and, in 2008, reached 2.5 billion people in the world[5].

From 2007 to 2010, 2,755,434 cases of acute diarrheal diseases (ADD) were reported in the state of São Paulo, Brazil. Estimates of incidence, both in general population and in the age group of children less than a year old and from one to four years old, were higher in 2010, ranging from 84.5 to 84.8/1,000 inhabitants, respectively. In the same period, 318 outbreaks of water and foodborne diseases were reported, 21.4% of which caused by food consumption and 12.5% by water[6].

We highlight that the alternative solutions of water supply for human consumption are the most vulnerable situations. They must be registered by sanitary surveillance and the quality of their water must be monitored frequently. Brazilian law[7] classifies them into two modalities: collective and individual. It defines the collective modality as “intended to provide drinking water, with underground or surface catchment, with or without plumbing and no distribution network”, and the individual modality as the one that “supplies households with a single family, including extended family members”.

Nevertheless, there are shortcomings in the data available on the registration of spouts and wells intended to or used for public supply as, for example, in the Metropolitan Region of Baixada Santista (MRBS), state of São Paulo[8], Brazil. The MRBS is composed of nine cities (Bertioga, Cubatão, Guarujá, Itanhaém, Mongaguá, Peruíbe, Praia Grande, Santos and São Vicente) and has a population of almost 1.8 million inhabitants[9], which can triple during summer season.

The ADD hospital admissions and their correlation with the quality of the water supplied to the population of Santos and São Vicente estuary region was studied between 2000 and 2010. In the cities of Cubatão, Guarujá, Bertioga, Santos and São Vicente there are several non-compliant areas that are not included in the neighborhoods supplied with water and sewer collection[4] by the local utility company. Over the studied period, we perceived a reduction of ADD in Bertioga and, to a lesser extent, in Cubatão[4].

However, water quality surveillance in the MRBS is usually done only in the water supplied by the concessionaire, according to the Program of Surveillance of the Quality of Water for Human Consumption - Proágua[10]. In this program, local sanitary surveillance agencies collect samples of treated or untreated water throughout the year and send them to be analyzed at the laboratory network of Adolfo Lutz Institute (IAL).

Several papers have been published in Brazil and abroad revealing water contamination in wells, spouts and sources, especially in wells [5, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22].

Official data published in 2005 about the natural chemical quality of wells located in the MRBS presents total iron as the more restrictive parameter, with an average value much higher than the legal maximum limit. However, this can be fixed through the aeration technique; next, there is chloride levels above the standard, especially in Santos and Cubatão, indicating contamination by seawater wedge[23].

This topic should be further researched in the MRBS, since there are only two published papers about it in recent literature[19, 20], one of which is restricted to the cities of Santos and São Vicente, therefore, not covering the other seven cities, in addition to the fact that only waterspout samples were collected.

It is noteworthy that in 2014 all Brazil suffered a water crisis that lasted well into 2015. That situation led to a greater demand for water from spouts, sources and artesian wells, whose quality is debatable.

In the light of the foregoing, this study aimed to evaluate the microbiological and physicochemical quality of water samples collected in spouts, sources and wells of the MRBS, based on Ministerial Act n. 2.914/2011, by the Brazilian Ministry of Health, which regulates the potability of water for human consumption[7].

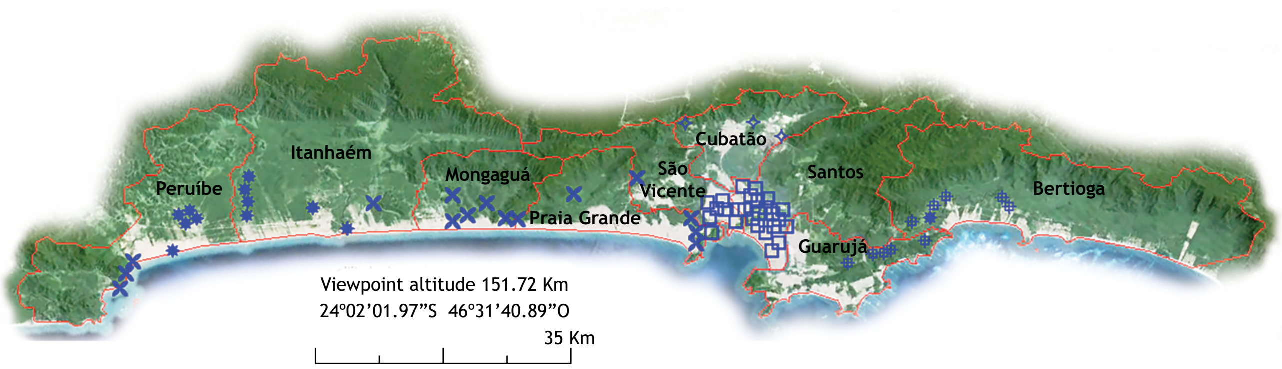
METHODS

As the first step, between November 2014 and January 2015, 67 samples, numbered from 1 to 67, were collected from the nine cities of the MRBS, 41 of which were from spouts, 13 from sources and 13 from wells. Later, 22 new samples were collected at the same sites, under the numbers of 68 to 89. The numbers were followed by the letters B, N or P, corresponding to spout, source or well, respectively.

Sample number 67, collected in Itanhaém, was the only one obtained out of the planned sequence because of a scheduling issue with the person responsible for the site. The figure shows the spatial distribution of these samples by city.

All sites were chosen based on archives of the institution, indication from local sanitary surveillance agencies or suggestion of local inhabitants.

The samples were kept under refrigeration and packed in polystyrene boxes until their arrival in the laboratory. The samples were analyzed for the presence of total coliforms and



Spouts and sources (Continental Area of São Vicente, Praia Grande, Mongaguá, Itanhaém and Peruíbe) Spouts, sources and wells (Bertioga and Guarujá) Spouts (Insular Area of Santos and São Vicente) Spouts and sources (Cubatão) Wells (Bertioga, Itanhaém and Peruíbe). Software used to build the figure: Photoshop. Image extracted from Google Earth (https://www.google.com.br/intl/pt-BR/earth/).

Figure. Spatial distribution of the water samples from spouts, sources and wells collected by city of the Metropolitan Region of Baixada Santista, state of São Paulo, Brazil, in the years of 2014 and 2015.

Escherichia coli, through the Colilert® defined substrate technique, Idexx brand, Idexx manufacturer, with capacity for a 100 mL sample, as described in the methodology of the American Public Health Association (APHA)[24], in addition to the following physicochemical parameters: chloride, free residual chlorine (in treated water), apparent color, hardness, iron, fluoride, nitrate, nitrite, odor, pH, total dissolved solids, sulphate and turbidity, following the techniques described in "Physicochemical methods for food analysis"[25].

Although the legislation considers the sample unsatisfactory simply through the detection of *E. coli*, we also quantified the total coliforms and *E. coli* through the chromogenic substrate with Quanti-Tray method, which consists of a sterile chart with 51 holes that uses the multiple-tube technique[24], since counting would better illustrate the level of contamination of the sample. The results were expressed through the Most Probable Number Chart (MPN/mL). Sample 33N was an exception, on which we only performed the research technique (presence or absence in 100 mL).

RESULTS AND DISCUSSION

Table 1 shows the results found in the analysis of the 67 samples collected in the first step.

Of all the 67 samples collected and analyzed, 56 (83.6%) were not in compliance with Ministerial Act n. 2.914/2011[7].

The tests with the highest percentages of unsatisfactory results in relation to the total were *E. coli*, 39 (58.2%); apparent color, 16 (23.9%) and nitrate, 15 (22.4%).

As the values applied to pH and Free Residual Chlorine (FRC) are only recommended by the legislation, they were not considered at the conclusion of the analysis. However, it should be noted that pH showed values below the fixed minimum limit (6) in 35 (52.3%) of the samples.

Table 2 shows the results found in the analysis of the 22 samples collected later.

It should be noted that only eight of the 22 samples collected later presented all analytical results similar to those found in the first collection. However, because they are sample analysis, it does not necessarily mean that the water was satisfactory at the sites, and a larger number of samples should be collected in order to be representative.

However, only four had the conclusion of their analysis changed: from satisfactory to unsatisfactory in two cases (69B and 78B) and the opposite in the other two (83B and 84B). Therefore, the quantitative and percentage results found in the first collection remain valid.

It is important to highlight that, for sample 35P, the result was unsatisfactory for iron and turbidity when collected in the first step. When it was collected again (69P), the owner of the property where the well was located reported that he emptied it and cleaned it when he was informed about the analytical results. The procedure proved to be effective as the conclusion of the new analysis was satisfactory.

Yet, another sample of the later collection (78B) was satisfactory for containing < 1 MPN/100mL versus only one unit when it was first collected. The pH value was below the minimum recommended (6) again, but this is not a reason to reject the sample[7].

Total coliforms are not pathogenic, but they indicate possible presence of human and animal waste in water, to be confirmed by *E. coli* testing[24]. The presence of this bacteria occurred in spout, source and well water of all the cities we analyzed.

The count of colony forming units of *E. coli* revealed four samples with values exceeding 2×10^2 MPN/100 mL, all pertaining to spout water: two in Peruíbe (65B and 66B) and two in Santos (46B and 47B). The first two also showed unsatisfactory results for apparent color and the other two for nitrate, highlighting that the samples are improper for consumption.

Apparent color is considered an aesthetic parameter, but high values (higher than 15 Hazen units) are unsuitable in sanitary

Table 1. Results obtained in the physicochemical and microbiological analysis of 67 samples of water from alternatives solutions in the metropolitan region of Baixada Santista, state of São Paulo, Brazil.

City	Sample No.	Odor	FRC (mg/L)	pH	Chloride (mg/L)	Apparent Color (UHz)	Hardness (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	TDS (mg/L)	Sulphate (mg/L)	Turbidity (uT)	Total C. (NPM/100 mL)	Thermo C. (NPM/100 mL)
São Vicente	1B	NO	NT*	5.8	25.4	1.3	19.9	0.1	0	7.1	0	61.1	9	0.2	200.5	1
	2B	NO	NT*	5.8	29.3	0.1	19.9	0.1	0	7.3	0	57.7	10	0.1	45.3	< 1
	3B	NO	NT*	5.6	15.6	0.8	58.3	0.3	0	2.7	0	69.4	30	0.1	> 200.5	1
	4B**	NO	0	5.2	23.4	0.7	31.3	0.1	0	20.1	0	59.2	7.4	0.1	> 200.5	69.7
	5B	NO	NT*	5.7	23.4	2.8	21.3	0.1	0	3.3	0	51.9	4.2	0.3	> 200.5	15
	6B	NO	NT*	5.6	23.4	6.7	39.8	0.1	0	2.6	0	59.4	15.9	0.7	> 200.5	200.5
	33N8	NO	0.09	5.5	7.8	89.9	35.8	0.08	0.17	0	0.05	24.34	0	13	Presence	Presence
Guarujá	7B	NO	NT*	7.1	31.2	2.2	11.4	0.1	0.07	0.2	0	48	6.9	0.3	62.4	< 1
	8N	NO	NT*	7.1	13.7	> 10	8.5	0.1	0.01	1.6	0	22.9	7.1	2.9	> 200.5	7.5
	9N	NO	NT*	6.4	11.7	> 10	8.5	0.1	0.04	2	0	25.1	8	4.2	> 200.5	2
	10B	NO	NT*	7	9.8	> 10	8.5	0.1	0.06	1.1	0	20	7.1	1.1	> 200.5	6.4
	11N	NO	NT*	7.1	9.8	< 5	9.9	0.1	0.03	0.7	0	22.1	6.7	1.8	> 200.5	7.5
	12N	NO	NT*	7.2	9.8	< 5	8.5	0	0.04	0.8	0	20.6	6.7	1.9	> 200.5	6.4
	13N	NO	NT*	6.7	11.7	5.5	11.4	0.1	0.05	0.5	0	27.3	6.2	0.9	> 200.5	9.9
	14B**	NO	1.39	7.2	19.5	7	11.4	0.1	0.02	1	0	37.9	7	1.1	0	< 1
	15N	NO	NT*	7.2	11.7	< 5	12.8	0.1	0.06	0.4	0	27	6.7	2.2	> 200.5	6.4
Itanhaém	16P	NO	0.05	5.4	13.6	25.8	28.6	0.04	0.62	0.7	0	160.8	2.1	0.5	< 1	< 1
	17P	NO	0.08	5.4	21.5	120.2	31.5	0.04	0.92	1.5	0.012	90.76	1.8	0.9	> 200.5	1
	18P	NO	0.1	4.8	25.4	163.4	27.2	0.03	0.08	0	0.015	42.14	2.7	1.1	> 200.5	< 1
	19P**	NO	0.05	4.5	13.6	28.6	24.3	0.03	0.3	0.7	0	35.22	1.9	0.7	1	< 1
	20P	NO	0.07	4.7	11.7	87.1	223.4	0.03	0.2	0	0.022	36.96	2.2	1.8	< 1	< 1
	21P**	NO	0.02	6.7	33.2	3.3	239.1	0.03	0.09	50.3	0.075	372.5	4.9	0.3	12,4	< 1
	22B	NO	0.01	5.8	11.7	0	32.9	0.04	0	0	0	29.12	3.7	0.3	> 200.5	4.2
	67P	NO	0.02	5.9	11.7	34.5	45.8	0.02	0.64	0.6	0	126.5	4.9	0.2	< 1	< 1
Cubatão	23B	NO	0.02	4.4	5.9	0	17.2	0.1	0	5.4	0	54.16	2.7	0.2	< 1	< 1
	24B	NO	0	6	7.8	0	28.6	0.1	0	9.6	0	74.07	5.4	0.3	< 1	< 1
	25B	NO	0.02	5.2	9.8	3.4	20	0.1	0	17.5	0	58.91	1	0.4	118.4	< 1
	26B	NO	0.02	6.9	5.9	6.8	20	0.1	0	11.4	0.1	48.59	4.1	0.4	> 200.5	65.9
Mongaguá	27B	NO	0.03	6.6	25.3	44	22.9	0	0	0	0	37.8	0.1	0.3	> 200.5	5.3
	28B	NO	0.01	5	21.4	0.2	31.5	0	0	0.1	0	68.8	0	0.1	129.8	1
	29B	NO	0.04	6.2	13.7	5.1	21.5	0	0	0.1	0	43.6	0	0.8	> 200.5	6.4
	30B	NO	0.01	5.1	11.7	55.6	21.5	0,1	0.02	0	0	53.2	0	0.6	16.4	< 1
	31B	NO	0.01	6.2	7.8	4.4	21.5	0	0.01	0	0	50.9	0	1.1	> 200.5	17.8
	32B	NO	0.02	5.5	31.2	0	24.3	0	0	0	0	91.1	0	0.3	> 200.5	6.4

Continues

Continuation

Bertioga	34N	NO	0.03	6.3	7.8	8.8	11.5	0.03	0.05	1.7	0	311.3	0	2.3	> 200.5	1
	35P	NO	0.06	6.3	15.6	13	44.4	0.06	0.51	0.7	0.005	313.4	0	5.4	16.4	< 1
	36N	NO	0.02	7.4	9.8	7.8	18.6	0.09	0.02	0.7	0	326.9	0	1.2	> 200.5	8.7
	37N	NO	0.02	6.9	21.5	10	11.5	0.05	0.03	1.4	0	335.7	0	4.6	> 200.5	78.2
	38N	NO	0.17	6.3	171.7	> 25	60.1	0.05	0.35	0.6	0.003	615.8	0	2.7	> 200.5	144.5
	39P**	O	0.12	4.8	54.6	> 25	18.6	0.04	2.41	0.4	0.011	389.5	0	6	< 1	< 1
Santos	40B	NO	0.03	6.3	42.9	20.5	42.9	0.2	0.02	17.2	0.011	138.9	15.8	1	> 200.5	13.7
	41B	NO	0	5.6	21.5	1.9	25.8	0.2	0	5.9	0	95.92	9	0.2	165.2	< 1
	42B	NO	0.01	6.4	33.2	7.3	28.6	0.2	0.01	2.3	0	304	7.3	0.6	> 200.5	17.8
	43B	NO	0	5.3	23.4	1.3	40	0.1	0	22.7	0	110	9.7	0.1	> 200.5	< 1
	44B	NO	0.04	5.2	29.3	0.7	34.4	0.1	0	4.8	0	121.1	12.5	0.1	109.1	< 1
	45B	NO	0.01	6.6	15.6	4.7	22.9	0.2	0	5	0	73.72	12.1	0.6	> 200.5	1
	46B	NO	0	5.4	29.3	8.6	74.5	0.2	0.03	40.1	0.004	349.7	25.1	0.7	> 200.5	> 200.5
	47B	NO	0.01	6.2	35.1	4.8	70.2	0.2	0.03	25.1	0	344.9	22.5	0.5	> 200.5	> 200.5
	48B	NO	0.02	6.3	7.8	2.6	7.2	0.2	0.01	0.2	0	42.7	0	0.3	> 200.5	< 1
	49B	NO	0.02	5.1	29.2	0	52.9	0.1	0.02	34.3	0	174.4	0	0.1	> 200.5	< 1
	50B	NO	0.02	5	25.4	0	45.8	0.1	0.02	24.7	0	133.7	0	0.2	< 1	< 1
	51B	NO	0.02	5.6	25.4	0	45.8	0.1	0	32.7	0	339.6	0	0.2	129.8	8.7
	52B	NO	0.02	4.8	29.2	0	64.4	0.2	0.01	34.3	0	194.9	9.2	0.1	36.4	3.1
	53B	NO	0.01	4.5	35.1	0	75.9	0.2	0.01	46.8	0	252.7	7.6	0.1	< 1	< 1
	54B	NO	0.02	5.3	23.4	0	38.7	0.1	0.01	18.9	0	330	0.7	0.1	50.4	< 1
	55B	NO	0.02	5.8	9.8	0	43	0.1	0.01	16.7	0	119.2	1.7	0.2	88.5	23.8
Praia Grande	56B	NO	0.02	6.4	11.7	12	7.2	0	0.02	0.7	0	123.3	4.4	0.4	> 200.5	45.3
	57B	NO	0.01	6.5	15.6	10.8	5.7	0	0.02	0.4	0	36.8	5.3	0.3	> 200.5	9.9
	58B	NO	0.01	5.5	35.1	1.9	18.6	0.1	0.03	3.5	0	111.4	5.4	0.5	> 200.5	< 1
Peruíbe	59P**	NO	0.01	4.5	13.7	33.4	34.4	0.04	2.14	1.2	0.007	142.3	7.6	2.4	< 1	< 1
	60P	NO	0.01	5.3	42.9	0	30	0.03	0	4.2	0	88.4	15.3	0.2	< 1	< 1
	61N**	NO	0.01	7.1	11.7	9.2	31.5	0.08	0	0.1	0	98.4	3.9	0.7	> 200.5	38.4
	62P**	NO	0	6.3	11.7	1.6	34.4	0.09	0	3.6	0	64.9	1.5	0.5	< 1	< 1
	63P**	NO	0.01	3.6	95.6	16.5	27.2	0.05	0.38	4.6	0	394.7	87.3	0.3	< 1	< 1
	64B	NO	0.02	6.6	19.5	24.6	22.9	0.04	0.02	0.7	0	57.6	4.9	1.5	> 200.5	23.8
	65B	NO	0.04	6.6	21.5	36.1	45.8	0.05	0.12	1.7	0	318.2	7.5	1.9	> 200.5	> 200.5
	66B	NO	0.04	6.7	15.6	15	37.2	0.04	0.01	0.7	0	314.1	7.4	0.4	> 200.5	> 200.5
Itanhaém	67P	NO	0.02	5.9	11.7	34.5	45.8	0.02	0.64	0.6	0	126.5	4.9	0.2	< 1	< 1

B: spout; N: source; P: well; ** Treated with chlorine; NO: Not objectionable; O: Objectionable; FRC: Free residual chlorine; NT*: not treated; TDS: Total dissolved solids; Total C.: Total coliforms; Thermo C.: Thermotolerant coliforms

Note: Because of technical issues, the test of total and thermotolerant coliforms was only done in 100 mL of sample 33N.

Table 2. Results obtained on the physicochemical and microbiological analysis of 22 samples of water from alternatives solutions in the Metropolitan Region of Baixada Santista, state of São Paulo, Brazil.

City	Sample No.	Odor	FRC (mg/L)	pH	Chloride (mg/L)	Apparent Color (UHz)	Hardness (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	TDS (mg/L)	Sulphate (mg/L)	Turbidity (uT)	Total C. (NPM/100 mL)	Thermo C. (NPM/100 mL)
Guarujá	68(7)(B)	NO	0.01	5.8	23.4	1	25.8	0.4	0.01	0.2	0.001	86.3	2.9	0>3	> 200.5	< 1
Bertioga	69(35)P	NO	0.03	6	17.6	> 15	53	0.3	0.29	0	0.005	76.7	8.1	2.3	0	< 1
Cubatão	70(25)B	NO	0.01	5.1	7.8	0	40.1	0.3	0.01	16	0.002	58.4	0	0.2	0	< 1
	71(26)N	NO	0.03	6.4	7.8	11	58.7	0.4	0.02	9.8	0.009	40.7	1.8	1.3	> 200.5	59.1
Santos	72(56)B	NO	0.01	5.5	15.6	13.2	40.1	0.1	0.01	13.8	0.004	331.1	5.1	0.3	> 200.5	144.5
	73(55)B	NO	0	5.1	19.5	0	38.6	0.1	0	19.4	0	119.8	1.3	0.2	> 200.5	1
	74(40)B	NO	0.03	5.7	29.3	0	44.3	0.1	0	19.4	0.047	172.6	3	1.8	200.5	200.5
	75(43)B	NO	0.03	6.2	15.6	30.9	45.8	0.1	0.01	18.2	0	325.5	0	0.3	200.5	< 1
São Vicente	76(4)B**	NO	0	6.1	17.6	0	37.2	0.1	0	18.6	0	127.7	0	0.5	109.1	1
	77(2)(B)	NO	0.01	5.3	27.3	0	18.6	0.1	0	5.9	0	128.1	0	0.3	4.2	< 1
	78(1)(B)	NO	0	5.1	31.2	0	21.4	0.1	0	5.4	0	226.5	0	0.3	6.4	< 1
Mongaguá	79(30)B	NO	0.01	5	15.6	2.4	10	0.1	0.09	1	0	65.42	0	0.8	1	< 1
Itanhaém	80(21)P**	NO	0.31	7	50.7	6.6	186.1	0	0	48.8	0.001	467.6	3.6	0.3	< 1	< 1
	81(19)P**	NO	0.05	4.5	13.7	28.5	14.3	0	0.27	2.8	0.001	172.2	0	0.3	< 1	< 1
	82(18)P	NO	0.07	4.5	13.7	156.1	15.7	0	1.94	0.1	0.013	56.29	0	2.7	< 1	< 1
Praia Grande	83(61)N	NO	0.02	5.1	29.3	6.4	15.7	0.1	0	1.5	0.001	57.23	0	0.4	> 200.5	15
	84(60)B	NO	0.03	5.1	31.2	1	20	0.1	0	3.2	0	119.1	0	0.5	> 200.5	4.2
Santos	85(50)B	NO	0	4.8	33.2	1.2	52.9	0.1	0	33.3	0	73.5	0	0.4	> 200.5	1
	86(51)B	NO	0	4.8	25.4	3.1	42.9	0.1	0	24.7	0.001	59.5	1.1	0.1	< 1	< 1
	87(52)B	NO	0.01	4.9	25.4	1.1	44.4	0.1	0.05	31.6	0.002	64.9	0.2	0.1	> 200.5	9.9
	88(53)B	NO	0.01	4.8	37,1	3.9	65.9	0.2	0	39.8	0	89.1	0	0.2	53.1	3.1
	89(54)B	NO	0	4.6	37.1	2.7	65.9	0.2	0.01	44.1	0.001	102.4	0	0.1	< 1	< 1

No. of previous collection; B: spout; N: source; P: well; ** Treated with chlorine; NO: Not objectionable; O: Objectionable; FRC: Free residual chlorine; NT*: not treated; TDS: Total dissolved solids; Total C.: Total coliforms; Thermo C.: Thermotolerant coliforms terms[7]. Some results far above the legal limit (15 Hazen units) were found, and the highest two (120.2 and 163.4) were obtained in samples of water from private wells in Itanhaém (17P and 18P, the latter collected again under the number 82P).

Nitrate above 10 mg/L assumes that the water was contaminated by sewage, animal or human waste and could pose a health risk[19]. The highest values were observed in water from a well in Itanhaém (50.3 mg/L), 21P, later collected again as 78P, and from a spout in Santos (46.8 mg/L), 53B, later collected again as 89B. In fact, the higher incidence of unsatisfactory results for nitrate occurred in the water samples collected in spouts in the mountains around Santos.

Vieira et al.[20] published a retrospective study about the microbiological and physicochemical quality of water of alternative supply solutions in the MRBS, from 2008 to 2014. The results showed that, of 305 samples analyzed, 84 (28%) were in disagreement with the laws in force at the time[7], and the most rejected parameters, in order, were apparent color, *E. coli* and iron, in 15%, 10% and 8% of the total. In the present experiment, as mentioned above, the incidence of rejections was higher and occurred in relation to *E. coli* (58.2%), apparent color (23.9%) and nitrate (22.4%).

Still with respect to nitrate, Scorsafava et al.[16] evaluated the quality of 1,356 water samples from wells and 403 from mines of 100 cities in the state of São Paulo, including the capital (the city of São Paulo), between 2005 and 2008. Nitrate was the parameter with highest percentage of unsatisfactory results in the average of the years (10.8% and 14.5%, respectively), followed by iron, with 8.5% of water samples from wells rejected, and color, with 9.6% of non-conformities in the water samples of mines. Nonetheless, in the current research, none of the 13 well water samples showed nitrate above the established limit.

Soto et al.[17] conducted a study in 2005 to analyze the microbiological and physicochemical quality of 50 water samples collected in wells in the public schools of the city of Ibiúna/SP. The most unsatisfactory results were total coliforms in 90% and *E. coli* in 82% of the total[17]. However, in this work, *E. coli* was present in 58.2% of the samples but none from well water.

In São José do Rio Preto/SP, 159 well water samples – mostly from irregular lots – were analyzed from September 2011 to June 2012 for physicochemical, microbiological and fungal indicators. Fungi appeared in 80% of the chlorinated and non-chlorinated water samples, in addition to the presence of *E. coli* and physicochemical parameters (apparent color, nitrate, turbidity and chlorine) at odds with the current law[12]. With the exception of chlorine and fungi, which were not analyzed, the other parameters were directly related to other contemporary results.

Araújo et al.[11], considering the great demand for well water in the state of Amazonas and the risk of the occurrence of several waterborne diseases, analyzed 962 water samples from wells in six zones of the city of Manaus during the rainy and dry seasons of the years of 2007 and 2008.

A 20% of non-compliant results were found in samples collected during the dry season and 34% in the rainy season. Most of the samples came from schools and may cause diseases like such as cholera in young children. The results showed pH values below the minimum (6) recommended by the legislation, although these values are typical of the Amazonian region[11]. In the present study, 52.3% of the samples presented pH lower than the minimum, showing the acidic character of these waters.

Campos et al.[13] did the microbiological evaluation of 4,653 samples of untreated water in 2012, collected in the state of Minas Gerais. The analysis was performed by the network of state public health laboratories and found the presence of total coliforms and/or *E. coli* in 42% of the total. They found clear contamination of the analyzed water samples by *E. coli*, although in a smaller percentage than what we found here, that was 58.2%.

Several spouts of Santos and São Vicente had unsatisfactory water quality according to a survey conducted in 2008[19], including Biquinha Padre Anchieta, a known tourist spot in the central region of São Vicente. Its water is chlorinated, according to information obtained from the local Health Department.

In the current study, sample 4B, new collection 76B, had nitrate content above the legal limit, contained *E. coli* (69.7 MPN/100 mL) and showed zero free residual chlorine, when the level recommended by legislation is 2 mg/L for chlorinated water[7]. The quality of its water has now worsened, as in the previous evaluation, pH was below the minimum recommended value (6) and nitrate was above the legally fixed maximum (10 mg/L)[7].

In turn, of the 13 samples of well water, seven had iron content above the maximum established limit (0.3 mg/L)[7]. Three of them were collected in Itanhaém (16P, 17P and 70P), three in Bertioga (35P, with new collection number 69P, 38N and 39P) and the other two in Peruíbe (62P and 66P). The highest value was verified in 39P (2.41 mg/L), that is, eight times higher than the fixed limit.

This finding is in disagreement with what was reported in 2005 for the water quality of the MRBS wells, when iron was the most unsatisfactory parameter, followed by chloride, since the latter was satisfactory in the 67 samples analyzed[23].

In the former capital of Nigeria, Lagos, Egwari and Aboaba[14] evaluated the bacteriological quality of water from wells and spouts used in domestic supply collected during periods of drought and heavy rains in 1998 and 1999. *E. coli* and other pathogens were isolated and there was greater contamination in surface wells during the rainy season. The main source was the discharge of sewage.

Concerning the countries of the Southeastern Asia Region, there is a number of problems that significantly affect the quality of the water available for drinking, of which the most important is the contamination by pathogenic microorganisms[21]. A study done in the largest cities of India in 2004 showed microbiological contamination in 64% of the 600 points of collection of water for consumption, 2.5% of which (11 of a total of 40) in deep tubular wells[21].

In addition to microbiological contamination, chemical pollution in the groundwater of the same region increased. Excess fluoride is a recognized problem in India and in some areas of Indonesia, Myanmar, Sri Lanka and Thailand[21]. Its occurrence is due to natural sources, but its long-term ingestion can cause fluorosis, which affects multiple tissues and organs of the human body, resulting in clinical manifestations[21].

Another survey was performed in Kathmandu Valley, Nepal, in 2001, with 100 water samples obtained from various points, including stone spouts and excavated wells [22]. In this work, as in those from Nigeria and in Asia herein, the biggest problem was total coliforms and *E. coli*, which were present in 94% and 72% of the samples, respectively. The contamination by ammonia and nitrate came next, with 45% and 11% of the samples, respectively. Nitrate had half the unsatisfactory analysis in Nepal compared to this study (58.2%), but the percentage of *E. coli* was higher, as found in Asia.

Considering the above, we recommend that the authorities take action to treat the aforementioned sources of water, including adopting measures like chlorination and filtration, aiming to improve the quality of the water supplied to the population by alternative supply solutions.

CONCLUSIONS

Considering these results, we suggest constant monitoring of the quality of the water from alternative supply solutions by sanitary surveillance bodies in the Metropolitan Region of Baixada Santista. It could be helpful to include them in the Proágua program again, for example.

Another suggestion is that the authorities implement actions like chlorination for the appropriate treatment of this water. It is necessary that the authorities and the media inform users as to the quality of these water sources.

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Conflict of interest

Authors have no potential conflict of interest to declare, related to this study’s political or financial peers and institutions.